

**Learning Objectives**

Students will develop skills with a digital multimeter, oscilloscope, and prototype circuit to prepare and collect data for time varying signals including non-periodic waveforms. Completing this lab will help ensure the student can:

1. apply the concepts and definitions of a step input and system time response in predicting the behavior of an RC analog circuit
2. demonstrate how step input and system response are related to measuring the charging or discharging capacitor as part of an analog circuit
3. determine appropriate statements of uncertainty for oscilloscope and multimeter measurements, and
4. collect and analyze data to characterize the behavior of an RC filter circuit
5. operate advanced functions of a laboratory oscilloscope to perform voltage measurements by capturing a non-periodic event in a time varying waveform from a RC Circuit,

**Background**

Consult the user manuals for the multimeter and the oscilloscope. Videos are provided to help learn the advanced features of the Tektronix TDS1000B oscilloscopes such as the capture trigger settings.

**Collaboration**

This challenge can be accomplished as an individual, but it will take careful planning to operate the equipment and record data at the same time. The quality of the experiment and recorded data may be improved with the help from a second person. Ask a peer or the TA to help if you are having trouble executing the activities alone. Collaboration is encouraged, but this is an individual assignment.

**Setup Notes**

In this activity, you will construct a RC circuit on a solderless breadboard and apply a step input voltage with the DC power supply. The digital multimeter and optionally the oscilloscope will be used to measure the voltage over time of the capacitor as it charges and discharges in response to this input. Watch the tips videos provided for information related to the equipment setup and experimental procedure.

**Activity 1 – Construct RC circuit**

Build the RC circuit shown in the background document on the solderless breadboard with given parameters R1 and C1. Verify the component values match the parameters provided before constructing the circuit.

Design the circuit so that it can quickly be powered to approximate a step change in the input voltage. This can be done with the DC power supply on/off switch or a simple connection with a jumper wire.

The capacitor must be discharged completely before proceeding. Leave the capacitor in the circuit and discharge the capacitor by connecting, or shorting, the two leads with a jumper wire. There is a low potential for a small electrical arc to occur. To reduce the risk of minor shock or burn, hold the jumper wire used by the insulated portion. The capacitor voltage should be near zero before you begin Activity 2.

**Activity 2 - Use multimeter to observe charging capacitor circuit response**

Use the multimeter to measure the output DC voltage across the capacitor over time after applying the input signal voltage to the circuit. The capacitor should be initially discharged. A suggested procedure is described below and demonstrated in the videos provided.

Before beginning, prepare a spread sheet to record voltage values at approximate sample times as the capacitor charges.

With the voltage supply connected and powered off, place the multimeter probes in the appropriate banana plugs on the breadboard or other hands-free location. Apply the step input signal using the power supply on/off switch so that the amplitude of the source voltage quickly changes from 0 to  $V_s$  volts.

Record the values for the measured output voltage with approximate sample times as the capacitor charges. The timing scheme shown below is recommended for capturing the expected response event. The speed of the system response will vary based on the system parameters, so the timing scheme used may need to be adjusted.

First 10 seconds: record every 2 seconds

Next 30 seconds: record every 5 seconds

Remaining time: record every 10 seconds

Continue recording until the output voltage has approximately reached steady state, and verify the capacitor voltage is approximately equal to the source voltage.

Remove the source voltage from the circuit by quickly disconnecting the banana plug (or use on/off button on power supply – TH check on this) from the circuit. In an ideal circuit, the capacitor would remain charged after the voltage supply is removed and the circuit is left open. Observe the behavior of the circuit you have constructed as you disconnect the power supply.

For best results, the capacitor voltage should be relatively close to the source voltage before proceeding. Recharge the capacitor if the voltage has changed significantly and leave the voltage supply connected and powered on. The re-charging event does not need to be measured.

**Activity 3 - Use multimeter to observe discharging capacitor circuit response**

Use the multimeter to measure the output DC voltage across the capacitor over time after removing the input signal voltage and closing the circuit with a conductor. The capacitor should be initially charged. A suggested procedure is described below and demonstrated in the videos provided.

Before beginning, prepare the spread sheet to record voltage values at approximate sample times as the capacitor discharges.

Disconnect the power supply from the circuit and turn off the power supply to prevent a short circuit. If the power supply is turned off first, the capacitor will immediately begin to discharge through the resistor and power supply which is not the desired experiment.

With the voltage source removed and the circuit open, quickly connect the free open side of the resistor to ground closing the circuit. It is not recommended to move the leads of the capacitor or resistor. A jumper wire can be used to make this connection. When the circuit is closed, the capacitor will begin to discharge, and the measurement process should begin immediately.

Record the values for the measured output voltage with approximate sample times as the capacitor discharges. The same timing scheme used in Activity 2 for measuring charging is appropriate for Activity 3.

**Activity 4 – Predict Expected Response with Ideal Circuit Model**

Use the ideal circuit model and analytical solution provided in the background to predict the expected behavior of the RC circuit. Show the output voltage response of the ideal circuit as a function of time during the charging and discharging events using a similar time span as in activities 3 and 4.

**Activity 5 (Optional) - Use Oscilloscope Trigger to Capture Event**

Recreate the charging and discharging event from activity 2 and record the response waveforms using the oscilloscope. Verify that the capacitor voltage is near zero before proceeding with activity 4. If needed, repeat the safe discharging procedure described in activity 1.

Without changing the RC circuit, connect oscilloscope to measure the voltage output across the leads of the capacitor. The ground cable on the oscilloscope must be connected to the negative side of the capacitor.

*Part 1 – Charging*

Adjust the trigger settings so that the charging event is shown on the display. Save an image of the oscilloscope display that shows the capacitor voltage from the time the voltage is applied until the signal reaches approximate steady state.

Document the oscilloscope settings and steps required to capture the circuit response.

*Part 2 – Discharging*

Adjust the trigger settings so that the discharging event is shown on the display.

**Observations and Discussion:**

During Activity 2, Activity 3 and Activity 4, the digital multimeter was used to measure the output voltage response from a RC circuit subject to a step input voltage, and the expected analytical solution was also determined. Compare the results from both methods and discuss what was observed from the comparison, including what can be declared regarding uncertainty for each method. Does the physical RC circuit behave like the model predicts? Can the component parameters be used to characterize the system?